

## CLAIMS

We claim:

- 1 1. A high-impedance optical electrode used for measuring bio-potentials
- 2 comprising:
  - 3 a) a light source;
  - 4 b) an electro-optic modulator:
    - 5 (1) receiving light from said light source;
    - 6 (2) modulating said light in response to a bio-potential; and
    - 7 (3) providing a modulated light output proportional to said bio-potential.

- 1 2. The high-impedance optical electrode used for measuring bio-potentials according
- 2 to claim 1 further comprising a photodetector for receiving and converting said
- 3 modulated light output from said electro-optic modulator to an electrical signal.

- 1 3. The high-impedance optical electrode used for measuring bio-potentials according
- 2 to claim 2 further comprising electronic circuitry for providing an electronic output
- 3 signal.

- 1 4. The high-impedance optical electrode used for measuring bio-potentials according
- 2 to claim 1 further comprising a pilot tone generated by said electronic circuitry and
- 3 superimposed on said bio-potential.

- 1 5. The high-impedance optical electrode used for measuring bio-potentials according
- 2 to claim 1 further comprising an optical splitter for splitting said light from said light
- 3 source into at least a second light portion.

- 1 6. The high-impedance optical electrode used for measuring bio-potentials according
- 2 to claim 5 wherein said second light portion is received by a second electro-optical
- 3 modulator.

1 7. The high-impedance optical electrode used for measuring bio-potentials according  
2 to claim 5 wherein said second light portion is used as an optical reference signal.

1 8. The high-impedance optical electrode used for measuring bio-potentials according  
2 to claim 1 further comprising an optical phase-shift modulator.

3 9. A high impedance optical electrode for measuring bio-potentials comprising:

4 a) a light source;

5 b) a bio-potential;

6 c) an electro-optic modulator;

7 (1) receiving light from said light source;

8 (2) modulating said light in response to a bio-potential; and

9 (3) providing a modulated light output; and

10 d) a photodetector for receiving and converting said modulated light output from  
11 said electro-optic modulator into an electrical output.

1 10. The high impedance optical electrode according to claim 9 wherein said  
2 electrical output is a voltage.

1 11. The high impedance optical electrode according to claim 9 wherein said light  
2 source is a laser diode.

1 12. The high impedance optical electrode according to claim 11 wherein said laser  
2 diode is a highly coherent laser diode.

1 13. The high impedance optical electrode according to claim 11 wherein said laser  
2 diode is a low coherent laser diode.

1 14. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein said light source is a distributed feedback laser .

1 15. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein said light source is a Fabry-Perot laser.

1 16. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein said light source is a vertical cavity surface-emitting laser.

1 17. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein said light source is connected to said electro-optic modulator with an  
3 optical fiber.

1 18. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein said electro-optic modulator is connected to said photodetector with an  
3 optical fiber.

1 19 The high impedance optical electrode for measuring bio-potentials according to  
2 claim 17 wherein said electro-optic modulator is connected to said photodetector with  
3 an optical fiber.

1 20. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein at least one end of said electro-optic modulator connected to at least  
3 one member of a group of members consisting of: an optical fiber, said light source,  
4 and said photodetector, is formed at an angle to vertical.  
*Fig. 8*

1 21. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein at least one end of said electro-optic modulator is connected to an  
3 optical fiber with an optical carrier.

1 22. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 21 wherein an end of said optical carrier connected to said electro-optic  
3 modulator is formed at an angle to vertical.

1 23. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein at least said electro-optic modulator is enclosed in a housing.

1 24. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 23 wherein said housing is hermetically sealed.

1 25 The high impedance optical electrode for measuring bio-potentials according to  
2 claim 23 wherein said housing is at least partially covered with electro-magnetic  
3 shielding.

1 26. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 25 wherein said electro-magnetic shielding is a conductive paint.

1 27. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 23 wherein said housing provides a ground return.

1 28. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 wherein said electro-optic modulator is a Mach-Zehnder interferometer.

1 29. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 28 wherein said Mach-Zehnder interferometer operates in a linear region.

1 30. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 28 with said Mach-Zehnder interferometer comprising:

- 3       a) a substrate having formed therein:
- 4           (1) a light input wave-guide receiving light from said light source;  
5           (2) a splitter connected to said light input wave-guide;  
6           (3) a first leg light wave-guide connected to said splitter;  
7           (4) a second leg light wave-guide connected to said splitter;  
8           (5) a combiner connected for receiving light from said first leg light wave-  
9           guide and said second leg light wave-guide; and  
10          (6) a light output wave-guide connected to said combiner.

1 31. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 30 wherein said substrate is crystalline.

1 32. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 30 wherein said substrate is crystalline.

1 33. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 30 wherein said crystalline substrate comprises  $\text{LiNbO}_3$ .

1 34. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 30 further comprising:

- 3       a) a bio-potential plate mounted on said substrate between said first leg light  
4       wave-guide and said second light wave-guide;  
5       b) a first grounding plate mounted on said substrate on a side of said first leg  
6       light wave-guide opposite said bio-potential plate; and  
7       c) a second grounding plate mounted on said substrate on a side of said second  
8       leg light wave-guide opposite said bio-potential plate.

1 35. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 34 wherein said grounding plates are connected to a ground return provided by a  
3 housing.

1 36 The high impedance optical electrode for measuring bio-potentials according to  
2 claim 34 further comprising a pick-up pad electrically connected to said bio-potential  
3 plate.

1 37 The high impedance optical electrode for measuring bio-potentials according to  
2 claim 36 further comprising of a shunt resistor connected to said bio-potential plate and  
3 said grounding plate.

1 38. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 30 wherein a spatial filter is mounted to an end of said substrate.

1 39 The high impedance optical electrode for measuring bio-potentials according to  
2 claim 30 further comprising a strap for securing said electro-optic modulator to a  
3 patient.

1 40 The high impedance optical electrode for measuring bio-potentials according to  
2 claim 30 further comprising a helmet for positioning at lease one of said electro-optic  
3 modulator on a patient.

1 41. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 40 wherein said helmet provides a ground return for said electro-optic modulator.

1 42. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 further comprising a bio-potential plate for receiving said bio-potential and  
3 modulating said light in response thereto.

1 43. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 42 wherein said bio-potential plate is electrically connected to a pick-up pad for  
3 acquiring said bio-potential.

1 44. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 43 wherein said pick-up pad is used without conductive ointments.

1 45. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 43 wherein said pick-up pad has an irregular surface.

1 46. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 43 with said pick-up pad comprising an electrically conducting disk.

1 47. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 43 wherein said pick-up pad is mounted to a housing for said electro-optic  
3 modulator.

1 48. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 42 wherein said bio-potential plate receives said bio-potential through clothing.

1 49. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 42 wherein said bio-potential plate receives said bio-potential as a result of  
3 capacitive coupling.

1 50. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 further comprising of an optical power splitter for receiving light from said light  
3 source and providing said light to at least two light receiving devices.

1 51 The high impedance optical electrode for measuring bio-potentials according to  
2 claim 50 wherein one of said light-receiving devices is a second photodetector.

1 52. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 51 wherein said second photodetector is a reference photodetector.

1 53. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 50 wherein one of said light receiving devices is a second electro-optic  
3 modulator.

1 54. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 50 wherein said optical splitter comprises an N-splitter.

1 55. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 50 wherein said optical splitter comprises an X:Y splitter.

1 56. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 further comprising a phase modulator receiving light from one of the light  
3 source and said electro-optic modulator.

1 57. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 56 with said phase modulator comprising a piezo-electric substrate having formed  
3 therein a light waveguide with a hot electrode and a ground electrode mounted  
4 opposite each other on each side of said waveguide.

1 58. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 57 further comprising a frequency generator for imposing a potential on said hot  
3 electrode with a frequency higher than a frequency range of said bio-potential.

1 59. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 9 further comprising electronic circuitry for processing said electrical output from  
3 said photodetector.

1 60. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 59 with said electronic circuitry comprising post photodetector processing.

1 61. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 59 with said electronic circuitry comprising DC transient suppression circuitry.

1 62. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 59 with said electronic circuitry comprising amplification circuitry.

1 63. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 59 with said electronic circuitry comprising filtering circuitry.

1 64. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 59 with said electronic circuitry comprising pilot tone generation circuitry.

1 65. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 59 wherein a pilot tone from said pilot tone generation circuitry is superimposed  
3 on said bio-potential at a frequency outside of the frequency range of said bio-  
4 potential.

1 66. The high impedance optical electrode for measuring bio-potentials according to  
2 claim 65 wherein said pilot tone is applied directly to a patient.